

## DISPLAY APPARATUS AND IMAGE SIGNAL PROCESSING APPARATUS

### BACKGROUND OF THE INVENTION

#### Field of the Invention

5           The present invention relates to a display apparatus as well as a signal processing apparatus for a display apparatus that is suitable for application to a large image plane/highly accurate display apparatus such as a liquid crystal display and a projector, etc.

#### 10   Related Background Art

          Advent of the multimedia age brings display apparatus to all the scenes, and since projection type display apparatus is efficient compared with other systems in particular, front projectors are in common  
15   use for presentations, etc. and rear projectors are in common use for domestic theaters.

          In recent years, CRT projection is being replaced by a projector in a liquid crystal panel system and a DMD (digital mirror device, for which reference should  
20   be made to Japanese Patent Application Laid-Open No. 10-78550) method modulating light quantity by changing angles of an mirror which are turning to spread because they are appropriate for providing high luminance and highly delicate accuracy.

25           However, these projection-type display apparatuses is inferior to CRT display tubes in general use in terms of picture quality, and for high picture quality

display (display demanded for quality feeling), users  
tend to use CRT display tubes even when the image plane  
size is small. High picture quality (quality feeling)  
herein referred to is high dynamic range (capability of  
5 high contrast and high gradation display).

Since a CRT, luminance of which can be modulated  
with electron beam intensification, etc., dynamic range  
can realize up to around 1000:1 in the case where only  
a particular range (a partial region) displays white,  
10 etc. Accordingly, its potentiality can make white  
brighter and black darker to realize excellent picture  
quality. However, in case of a CRT system, the size  
thereof is around 40 inches at largest due to  
limitation in a tube, etc., giving rise to a problem  
15 that there exists a high degree of technological  
difficulty for larger sizes.

On the other hand, in a projection-type display  
apparatus, a CRT system is traded off in terms of its  
engine size, brightness and high accuracy, etc, and as  
20 described above, a liquid crystal system as well as a  
DMD system is suitable for high luminance and high  
accuracy is recently in a main stream. In these cases,  
the liquid crystal and the DMD are assigned to play  
roles of a light modulator, and a lamp illuminates the  
25 above described liquid crystal device or DMD to be  
enlarged for projection by a projection optical system.  
Accordingly, the above described dynamic range is

determined with the dynamic range mainly provided by the liquid crystal device or DMD.

The practical dynamic range of the above described device is approximately 300 to 400: 1 for liquid  
5 crystals and approximately 500 to 600: 1 for DMDs. Accordingly, they used to have a problem that there is a long way to win against the above described CRT system in terms of one point of high picture quality (high dynamic range).

10 In addition, a direct-view-type LCD likewise used to have a problem that its dynamic range is low, compared with the CRT.

Incidentally, as background documents of the present application, Japanese Patent No. 2643712,  
15 Japanese Patent Application Laid-Open No. 6-102484 and Japanese Patent Application Laid-Open No. 11-65528 and Japanese Patent Application Laid-Open No. 6-167717 are nominated.

## 20 SUMMARY OF THE INVENTION

An objective to be solved by the present invention application is to realize high picture quality in a projection-type display apparatus or direct-view-type apparatus irradiating lights to a light modulating  
25 element to construct display image planes by its penetrating light or reflected light.

Another objective of the mode of embodiments of

the present application is to provide a system to attain high picture quality of a high dynamic range to be attached to features of large image plane and high accuracy of the projection-type display apparatus.

5           Moreover, the above described system is to attain the above described objective with an existing device, which might be a liquid crystal device and DMD having levels thereof, in combination, and is a low-cost and practical system.

10           In addition, the objective includes providing a system to attain high picture quality of high dynamic range to be attached to features of high degree of resolution in a direct-view-type liquid crystal display apparatus provided with back light.

15           One aspect of the present invention application is constructed as follows.

          A display apparatus irradiating light generated by a light source onto a light modulating element and forming a display image plane with the light  
20           transmitted through or reflected by the light modulating element, comprising:

          input image calculating means for performing predetermined calculation according to an input display signal;

25           light quantity controlling means for controlling light quantity irradiated onto the above described light modulating element according to a result of the

above described calculation; and

a memory for storing display signal subjected to the above described calculation by the input image calculating means, and for outputting thereafter the display signal to the above described light modulating element.

Here, the display signal is referred to as an image signal and an image data to be inputted.

In this invention, a memory is provided so as to temporally store the display signal after calculation, and therefore, even if light quantity control takes time, it will become possible that the signal to be inputted to the light modulating element are easily brought into synchronization with the light quantity control corresponding with the signals.

Another aspect of the present invention is constructed as follows.

A display apparatus irradiating light generated by a light source onto a light modulating element inputting a modulated signal formed by converting display signal inputted in an analog state into digital display signals and thereafter subjected to the converted digital display signal to a predetermined processing, and forming a display image plane from the light which transmitted through or reflected by the light modulating element, comprising:

input image calculating means for performing

predetermined calculation according to the display  
signal;

light quantity controlling means for controlling  
light quantity irradiated onto the above described  
5 light modulating element according to a result of the  
above described calculation; and

an adjusting circuit for adjusting display signal  
according to a result of the above described  
calculation,

10 wherein the above described adjusting circuit  
adjusts display signal before the conversion of the  
display signal in the above described analog state into  
the digital display signal.

Incidentally, in this invention, the display  
15 signal to undergo calculation may be in an analog state  
or may be those having undergone digital conversion.

In addition, adjustment referred to herein is  
exemplified by amplification.

In addition, prior to inputting to the modulating  
20 element, signal may be converted into analog display  
signal again after that is converted from analog  
display signal to digital display signal and undergo a  
predetermined processing.

In addition, another aspect of the present  
25 invention is constructed as follows.

A display apparatus irradiating light generated by  
a light source onto a light modulating element and

forming a display image plane from the light  
transmitted through or reflected by the light  
modulating element:

input image calculating means for performing  
5 predetermined calculation according to the display  
signal; and

light quantity controlling means for controlling  
light quantity irradiated onto the above described  
light modulating element according to a result of the  
10 above described calculation,

wherein the above described light quantity  
controlling means sets a change rate when the above  
described light quantity is decreased to a smaller one  
than a change rate when the light quantity is  
15 increased.

The change rate referred to herein is in  
particular the one obtained by dividing the difference  
between the light quantity at start of change and the  
light quantity at completion of change with time from  
20 start of change to when to reach a desired light  
quantity.

In addition, another aspect of the present  
invention is constructed as follows.

A display apparatus irradiating light generated by  
25 a light source onto a light modulating element and  
forming a display image plane from the light  
transmitted through or reflected by the light

modulating element, comprising:

input image calculating means for performing predetermined calculation according to an input display signal; and

5 light quantity controlling means for increasing or decreasing a light quantity irradiated onto the above described light modulating element step by step according to a value determined by result of the above described calculation,

10 wherein a threshold value at which the above described light quantity controlling means increases a first stage being a predetermined stage to a second stage by increasing the above described light quantity by one stage corresponding with a value determined by  
15 the above described calculation is different from a threshold at which the above described second stage is decreased to a stage with less light quantity.

Here, the above described light quantity  
controlling means preferably set so as to increase the  
20 above described light quantity from the above described first stage to the above described second stage when the value determined by the above described calculation changes in the first direction to exceed the first  
threshold value, and so as to decrease the above  
25 described light quantity from the above described second stage to a stage with less light quantity when the value determined by the above described calculation

changes in the second direction being opposite against the above described first direction to exceed the second threshold value set in the side of the above described second direction than the above described first threshold value. In addition, here the stage of the above described low light quantity being the above described first stage can be controlled easily.

In addition, the aspects of the present invention described above suitably have adjusting circuits to adjust display signals corresponding with outcomes of the above described calculation. In addition, in the case where in the above described input image calculating means, a memory to store and thereafter output display signals having become an object for calculation toward the above described light modulating element, positions where the memory is provided can be appropriately set. For example, it can be provided in the preceding stage of the adjusting circuit.

Incidentally, various setting is possible for adjustment executed by this adjusting circuit, and in case of executing amplification, for example, a construction to amplify display signals at an amplifying ratio approximately in inverse proportion to light quantity illuminated to the above described light modulating element can be suitably adopted.

In addition, in the aspects of the present invention described above, such constructions that the

above described calculation could be calculation to give maximum luminance in the above described display signals inputted within a predetermined period or could be calculation to give a certain number of data

5 exceeding a predetermined luminance in luminance data that the above described display signals to be inputted within a predetermined period include can be suitably adopted. Here, as the predetermined period, 1 frame time or 1 field time in the case where 1 frame is  
10 constructed with a plurality of fields can suitably be adopted. In addition, for a section to count the above described luminance data, luminance data corresponding with one pixel is would be better to count as one luminance data.

15 In addition, the above described aspects of the present invention further have sensors to detect light quantity illuminated onto the above described light modulating element, suitably wherein the above described light quantity controlling means control the  
20 above described light quantity based on the above described calculation results and results detected by the above described sensors.

In addition, the display signals are adjusted corresponding with the above described calculation  
25 results, the adjusting circuit can suitably adopts a construction to execute the above described adjustment corresponding the above described calculation results

and the results detected by the above described sensors.

In addition, the aspects of the present invention described above can suitably adopt a construction to  
5 comprise irradiation light quantity changing quantity setting means to set changing quantity or change rate of the above described irradiation light quantity.

In addition, the aspects of the present invention described above can suitably adopt such construction  
10 that the above described light quantity controlling means are means to be disposed between the above described light source and the above described light modulating element to control light quantity to be  
15 irradiated to the above described light modulating element from the above described light source or such construction being means to control voltages or currents to be supplied to the above described light source.

Incidentally, the aspects of the present invention  
20 described above can be used appropriately in combination.

In addition, the present application includes an invention of the image signal processing apparatus to be used in the above described display apparatus.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing electric system

related to a first embodiment;

Fig. 2 is an explanatory view showing display examples according to the present invention;

Fig. 3 is a block diagram showing a processing  
5 flow according to a first embodiment of the present invention;

Fig. 4 is a flow chart according to the first embodiment of the present invention;

Fig. 5 is a block diagram showing a second  
10 embodiment;

Fig. 6 is a block diagram showing a third embodiment;

Fig. 7 is a flow chart showing a processing method of the third embodiment;

Fig. 8 is a block diagram showing a fourth  
15 embodiment;

Fig. 9 is an explanatory view showing a processing flow of a unit of calculating irradiation modulating factor of a fourth embodiment;

Fig. 10 is a schematic view showing a construction of an optical system for a liquid crystal projector related to a fifth embodiment of the present invention;

Fig. 11 is a schematic view showing a variation of the light modulator portion in Fig. 10;

Fig. 12 is a flow chart showing operation of the  
25 light modulator in Fig. 11;

Fig. 13 is a construction view showing an optical

system of a DMD projector related to a sixth embodiment of the present invention; and

Fig. 14, composed of Figs. 14A and 14B, is a block diagram showing a construction of a electric system of a DMD projector related to a seventh embodiment of the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

A display apparatus according to a preferred embodiment of the present invention is characterized in that it is provided with means to adjust light quantity to illuminate a light modulator (a liquid crystal device and a DMD), a circuit for processing a signal to the light modulator based on the above described illuminated light quantity and means for writing in that signal.

A projection-type display apparatus related to a preferable embodiment of the present invention is, as its features, provided between a light source and a light modulator (a liquid crystal device and a DMD) means (irradiation light quantity modulating means) to adjust light quantity to illuminate the above described light modulator, a circuit for processing a signal to the light modulator based on the above described illuminated light quantity and means for writing in that signal.

The above described signal processing circuit may

comprise amplifying means to amplify an input image signal at an amplifying ratio in inverse proportion to the above described light quantity or light quantity controlling signals.

5           According to the present invention, provision of irradiation light quantity modulating means to adjust light quantity illuminated onto the light modulator can make it possible to illuminate a dark image plane with low light quantity and a bright image plane with high  
10 light quantity, and consequently to realize a dynamic range higher than in the case where the light modulator is illuminated with constant light quantity.

          In addition, controlling the light quantity and the signal amplifying ratio in approximately inverse  
15 proportion by means of the signal processing circuit to become an adjusting circuit to adjust the above described display signals and the signal write-in means, high dynamic range can be realized while maintaining display luminance in an intermediate  
20 gradation at a constant.

          The above described irradiation light quantity modulating means may be the one to directly control a light source generating a light to be caused to illuminate the light modulator or the one to be  
25 provided between the light source and the light modulator to modulate transmissivity of the irradiation light quantity. As the former, means to control

voltages or currents to be supplied to the light source and as the latter the one which has means to convert a light flux from the light source into a polarized light flux together with the polarizing plate or a phase plate disposed capable of rotation in combination can be exemplified.

[Embodiments]

With reference to the drawings, embodiments of the present invention will be described below.

10 [Embodiment 1]

Fig. 1 shows a block diagram of a signal processing apparatus related to an embodiment of the present invention.

In Fig. 1, reference numerals 18, 17 and 16 denote liquid crystal panels in correspondence with R, G and B color display respectively, reference numeral 54 denotes a driver circuit to supply each liquid crystal panel with applying signals and power source, reference numeral 55 denotes a DA converter and reference numeral 56 denotes a memory. The memory 56 holds current display data as well as data to be displayed in the next frame and the like. Reference numeral 57 denotes a DSP unit to execute not only processing such as gamma adjustment, conversion of interlace signals to non-interlace signals, resolution conversion in the case where the pixel amount of liquid crystal panel currently in use does not corresponds with the pixel

amount of the input signal and color adjustment, etc.  
but also operation to calculate signal levels of  
respective colors for irradiation light quantity  
control. Reference numeral 58 denotes a timing  
5 generator circuit and reference numeral 59 denotes a  
remote controller to execute power source ON-OFF  
switching as well as respective kinds of settings.  
Reference numeral 60 denotes a control panel for  
receiving signals from the remote controller and  
10 executing respective kinds of input signal switching,  
etc. and reference numeral 61 denotes a driver for  
ultrasonic motor for modulating (controlling)  
irradiation light quantity and reference numeral 62  
denotes an ultrasonic motor. Reference numeral 63  
15 denotes a microcomputer to which the memory 56, the DSP  
unit 57, the timing generator circuit 58, the control  
panel 60, the USM driver 61, the power source 66 and a  
ballast for a lamp 64, etc. are brought into connection  
via a bus to control those respective blocks. The lamp  
20 65 is connected with the ballast 64. Reference numeral  
67 denotes an A/D converter and reference numeral 68  
denotes a switch. Reference numeral 69 denotes a  
signal processing circuit, which executes signal  
processing such as decoding NTSC signals, noise  
25 reducing processing, band limitation filtering and  
signal level adjustment, etc. Reference numeral 71  
denotes a PC (personal computer) input terminal and

reference numeral 72 denotes an NTSC input terminal,  
but in the present block diagram, only an analog input  
signal is indicated, but without limitation thereto, it  
goes without saying that input terminals such as LVDS  
5 and TMDS, etc. and a D3 terminal for a digital TV, etc.  
may be provided to function effectively. Reference  
numeral 75 denotes a sound input terminal, reference  
numeral 76 denotes a sound switching switch, reference  
numeral 70 denotes a sound processing circuit,  
10 reference numeral 73 denotes a speaker and reference  
numeral 74 denotes an AC inlet.

With reference to an electric block diagram in  
Fig. 1, basic operation on driving the irradiation  
light quantity modulation system of the present  
15 embodiment (operation of a system to write signals into  
a liquid crystal panel corresponding with a maximum  
luminance level determined by image signals) will be  
described.

Signals inputted from the input terminals 71 and  
20 72 are converted into digital signals via an AD  
converter 67 and temporally stored into the memory 56.  
At that time, the maximum luminance level at that frame  
is calculated, and currents or voltages to be supplied  
to the light source via rotation angle of the  
25 polarizing plate or phase plate or ballast 64 with  
which irradiation light quantity corresponding with  
that maximum luminance level is obtained are

calculated, and signals to realize a desired luminance at each pixel when the irradiation light in that light quantity is illuminated onto the panels are calculated and written. Signals from the memory 56 are read out  
5 in synchronization with light quantity control corresponding with signals being stored. A method of calculation of the above described maximum luminance level will be described later.

With reference to Fig. 2, a relationship between  
10 light quantity modulation and signal gains in respective display images will be described.

(a) of Fig. 2 shows images at the time t1 in which the sun is coming down below a mountain while the recess of a mountain and the sky are becoming dark.  
15 Numerical values in Fig. 2 represent luminance levels of that image. (b) of Fig. 2 shows an image after time has lapsed than (a) of Fig. 2, and the picture gets further darker subject to sunset. The peak at that time reaches 80% level compared with the preceding  
20 frame (a). The case (c) where time has further lapsed to enter night with the moon appearing in the sky so that the maximum luminance level reaches 30%.

Here, with respect to each image data, for (a) a light of 100% level is illuminated to the liquid  
25 crystal panel, for (b) a light of 80% level and for (c) a light of 30% level is illuminated. The displayed images for respective cases will become (a'), (b') and

(c'). Here, the reduced portion of the irradiation light is supplemented by amplifying signals. In (a') of Fig. 2, due to absence of drop in light quantity, the amplifying ratio is set at 1, in (b') of Fig. 2, the amplifying ratio is set at 1.25 times and in (c') of Fig. 2, the amplifying ratio is set at 3.3 times. They will result in (a''), (b'') and (c'') of Fig. 2 so that display luminance is maintained.

As described so far, combination of amplifying light quantity modulation and signals will enable improvement in dynamic range by broadening a displayable gray scale near a black level while maintaining display luminance.

With the dynamic range of the liquid crystal being 200:1, black levels of luminance level of not more than 0.5 cannot be displayed when 100% light quantity is illuminated, but according to the present embodiment, as the entire image plane is getting darker, the displayable range of the black level gets broader, and therefore further enhanced black display can be realized. In the case where the entire image plane is bright or is influenced by reflection lights from external lights, the recognition level on delicate difference of the black level could drop to human eyes, and reproducibility of black will not be so remarkable. However, as a scene gets darker, that reproducibility becomes important, but that is matched the above

described technology, and in case of the above described embodiment, the dynamic range will be practically improved to reach approximately 660:1.

In case of such a source with a lot of dark image  
5 scenes as in films, etc., the present effect is enormous, and images with good reproducibility of black and with improved dynamic range have become available.

In the present embodiment, a method to improve the dynamic range with the reduced portion of the  
10 irradiation light being supplemented by amplifying signals while display luminance is maintained has been described, a method to cause the signal gain to exceed the reduced portion of the irradiation light in order to use the dynamic range of the LCD effectively is  
15 effective.

Next, how to calculate a maximum luminance from image signals in further particular, moreover how to calculate a desired irradiation light quantity level from that calculated maximum luminance data, and how to  
20 determine an amplifying ratio of image signals from the irradiation light quantity level will be described in detail.

Maximum luminance is calculated by sequentially comparing input image data inside 1 frame or 1 field.  
25 In this case, since comparison on every pixel could lead to miscalculation of maximum luminance due to influence of noises, etc., it is also effective that

the maximum luminance is calculated by comparing values undergoing averaging (or averaging with weight) several pixels in the vicinity of the target pixel as respective pixel values.

5           Fig. 3 is a block diagram to describe processing inside a DSP, and Fig. 4 is a flow chart.

Based on an input signal 301 inputted from an input end 301, a luminance distribution calculating unit 302 calculate the maximum luminance (S402) as described above, and based on that result, irradiation light quantity is determined by an irradiation light quantity calculating unit 303 (S403). In addition, a unit of calculating quantity of controlling light quantity 304 determines the controlling light quantity (S404). Next, a unit of calculating amplifying ratio 305 determines an amplifying ratio so as to maintain the projected display luminance (S405), and an image signal amplifying unit 306 being writing signal conversion means amplifies the input signals 301, which is outputted as output signals 307.

10  
15  
20

Incidentally, for a circuit for writing signal conversion, a multiplier may be used or a conversion table (LUT: Look Up Table) may with which conversion features can be set further in detail may be used. In addition, a dynamic range adjusting circuit already existing in an image signal processing circuit (for example the signal processing circuit 69 in Fig. 1 and

25

the image signal processing unit 508 in Fig. 5) may be used.

[Embodiment 2]

In Embodiment 1, a construction using a liquid  
5 crystal panel as the light modulating element has been described, but in the present embodiment, as the light modulating element, a light modulating element, also known as a DMD, displaying images by integrating micromirrors and controlling reflecting directions of  
10 irradiation lights with respective mirrors is used. Description on portions in common with Embodiment 1 will be omitted.

Fig. 5 is a block diagram involving units of calculating quantity controlling light quantity and of  
15 signal gain setting related to a second embodiment of the present invention.

In Fig. 5, the image signals inputted from the signal input terminal 501 are amplified by an analog amplifying unit 502 constructing an adjusting circuit  
20 at an amplifying ratio calculated by a unit of calculating amplification ratio 507. Next, subject to conversion into digital signals with an A/D converter 503, a luminance detection unit 504 constructing input image calculating means determines the maximum  
25 luminance. Incidentally, in the present embodiment, since the maximum luminance is determined after amplification, the maximum luminance is determined in

consideration of an amplifying state. Corresponding  
with the maximum luminance, a unit of calculating  
irradiation light quantity 505 calculates an  
irradiation light quantity, and the next unit of  
5 calculating quantity of controlling light quantity 506  
determines a calculating quantity of controlling light  
quantity. Light quantity controlling means are  
constructed by the unit of calculating light quantity  
505 and the unit of calculating quantity of controlling  
10 light quantity 506. The amplifying ratio is given by  
the above described unit of calculating amplification  
ratio 507, and with a result thereof an amplification  
ratio of the above described analog amplifier is  
determined. The signal processing unit 508 executes  
15 respective kinds of signal processing other than  
irradiation light quantity controlling. Signals  
outputted by the signal processing unit 508 are written  
into a DMD panel 510 via a DMD driver circuit 509.

Fig. 5 shows the one to realize the signal gain  
20 setting unit in Embodiment 1 with an analog circuit,  
and to work well if it comprises an amplifier with a  
variable amplification ratio and an A/D converter with  
a variable reference voltage setting.

Moreover, a method of providing with a reference  
25 voltage is devised so that non-linear amplification  
will become possible and as a result thereof, gradation  
reproducibility will become improvable.

Amplification of image signals based on light quantity controlling at a stage of analog signals prior to undergoing conversion with an A/D converter will serve to make errors due to quantification controllable compared with Embodiment 1 and also in an image with improved dynamic range, good image quality with less deterioration in gradation will become available.

Application of the present invention to a DMD will become able to improve deterioration in image quality resembling particles due to binarization processing such as error proliferation, etc. at the side of low luminance peculiar to the DMD by way of extension of signal levels in addition to improvement in dynamic range.

In the present embodiment, a case of a DMD panel has been described, but a case of a liquid crystal panel can be done likewise.

[Embodiment 3]

Fig. 6 is a block diagram of a light quantity controlling unit and a signal gain setting unit related to a third embodiment of the present invention. In the present embodiment, light quantity controlling is executed by feeding back light quantity being illuminated to a light modulating element to a calculating unit.

In Fig. 6, based on image signals inputted from an input end 601, a luminance detection unit 602

calculates luminance distribution and a unit of  
calculating irradiation light quantity 603 calculates  
irradiation light quantity. Next, a unit of  
calculating quantity of controlling light quantity 604  
5 calculates quantity of controlling light quantity and  
an irradiation controlling apparatus 608 drives  
irradiation 609.

A sensor of detecting irradiation light quantity  
610 detects luminance of irradiation light 609 to be  
10 given to the unit of calculating quantity of  
controlling light quantity 604 as well as to the gain  
calculation unit 605. The gain calculation unit 605  
determines gains to be written into a panel,  
corresponding with the irradiation light quantity to be  
15 set or the detected irradiation light quantity. Input  
signals 601 is inputted to the gain unit 606 which  
changes input-output features corresponding with  
coefficients determined by the gain calculation unit  
605. The signal processing unit 607 executes  
20 respective kinds of signal processing and transmits  
image signals to a panel driving circuit (for example,  
the panel driver 54 in Fig. 1).

Next, with reference to a flow chart in Fig. 7, a  
processing/controlling method will be described.

25 At first, desired irradiation light quantity  
(S701) determined by image signals is compared with the  
light quantity at present (S702) obtainable from the

sensor of detecting irradiation light quantity. Here,  
a trend of change in irradiation light quantity is  
determined based on whether the desired irradiation  
light quantity is larger or not (S703). Next, time  
5 constant calculation means calculate changing quantity  
per control cycle. Next, changing quantity of  
irradiation light quantity corresponding with  
respective trends is calculated (S705), and a motor is  
controlled corresponding with that changing quantity  
10 (S706). Next, a light quantity detector detects  
irradiation light quantity after control (S707) and the  
stage returns to S701.

The step S708 calculates a signal level  
appropriate to light quantity at present so as to  
15 determine amplification ratio for signals and execute  
conversion into signals to be written for light  
modulator (S709). Here, the step S703 may be executed,  
as shown with a broken line, based on irradiation light  
quantity determined at the step S706.

20 The sensor to detect the irradiation light is  
disposed, as shown in a later described embodiment, in  
such a position that lights inside light paths or  
leaked lights can be detected in order to detect lights  
in proportion with incident lights to the light  
25 modulator.

Here, in the case where a feedback system as the  
present embodiment is not used, this control flow can

be used with the irradiation light quantity at present used in the step S702 being a value having been set previously in the step S707.

Here, the time constant is determined by motion  
5 velocity of a motor and a time period from supply of a control signal to the motor to completion of motion corresponding with the control signal, etc.

Accordingly to the present embodiment, with the sensor to detect the irradiation light quantity,  
10 feedback control is executed so that setting of irradiation and setting of signal amplifying ratio will become executable accurately, giving rise to an effect that luminance of the display image can be controlled stably.

15 In addition, in particular, the case where a motor with slow motion velocity is used or speed control for control of a motor is executed with time constants, etc. gives rise to effects.

[Embodiment 4]

20 Fig. 8 is a block construction diagram showing a display apparatus including a signal processing apparatus according to the present invention. This drawing includes portions in Fig. 1, one being equivalent to the DSP 57 and others being related to  
25 controlling in particular in the present embodiment. Incidentally, the present embodiment is arranged to execute synchronization between the display signals and

the light quantity control timings with a control  
signal delay unit 110 separately provided apart from  
the memory 56 in Fig. 1. In the present embodiment, a  
case of irradiation light quantity to be illuminated  
5 onto the display device such as an LCD, etc. being  
modulated uniformly on the display device will be  
described.

In Fig. 8, reference numeral 101 denotes an image  
input terminal, reference numeral 102 denotes a gain  
10 (dynamic range) controlling unit, reference numeral 103  
denotes a signal processing unit, reference numeral 104  
denotes a unit of  $\gamma$ -conversion, reference numeral 105  
denotes a D/A converter, reference numeral 106 denotes  
a display device such as an LCD, etc., reference  
15 numeral 107 denotes a unit of calculating irradiation  
modulating factor, reference numeral 108 denotes an  
irradiation modulating device driver and reference  
numeral 109 denotes an irradiation modulating device.  
In addition, reference numeral 110 denotes an image  
20 signal delay unit and reference numeral 111 denotes a  
control signal delay unit.

The image signals inputted by the image input  
terminal 101 are inputted to the unit of calculating  
irradiation modulating factor 107, where quantity of  
25 controlling light quantity to be outputted to the  
irradiation modulating device driver 108 as well as  
quantity of controlling gain to be outputted to the

gain control unit or the  $\gamma$ -unit are calculated.

With reference to Fig. 9, operation steps inside the unit of calculating irradiation modulating factor 107 in Fig. 8 will be described. The image signals inputted by the image input terminal 101 in Fig. 8 are inputted to the unit of calculating irradiation modulating factor 107 so that a unit of calculating luminance distribution 107-1 calculates luminance distribution. Here, as luminance distribution, maximum value, minimum value, average value and histogram, etc. of image signal data of one image plane or a plurality of image planes are calculated.

Next, a unit of detecting irradiation light quantity 107-2 calculates a light quantity value to become an aim based on a result of calculation of luminance distribution. Details on a method for calculation will be described later. In "processing flow 1" as well as "processing flow 2" to be described later, a flow using the maximum value of luminance will be described while in "processing flow 3" a method using histogram of luminance will be described.

Next, the unit of calculating quantity of controlling light quantity 107-3 calculates quantity of controlling light quantity based on the aimed light quantity value. Here, with the light quantity value to become an aim being larger than the light quantity value at present, the time constant calculation unit to

be described later determines a light quantity control signal so that the light quantity increases only by a value determined in advance, and on the contrary with the light quantity value to become an aim being smaller than the light quantity value at present, a light quantity control quantity is determined so that the light quantity decreases only by a value determined in advance.

Next, the unit of calculating signal gain 107-4 determines gain as well as off setting of image signals in correspondence with the light quantity determined by the above described the above described control signal. Here, (irradiation light quantity)  $\times$  (signal gain) is controlled to be always a constant so that brightness of displayed image is maintained.

The above described time constant setting unit 107-5 sets changing quantity of light quantity. Here, change rate of light quantity may be a constant, or may be changed according to a difference between a target value and the value at present, but in a trailing edge trend (a trend where irradiation light gets dark), image signals are amplified by decrease in light quantity and luminance to be displayed can be reproduced regardless of speed of control, but in a leading edge trend (a trend where irradiation light gets bright), luminance to be displayed cannot be reproduced by changing image signals if the speed to

brighten the irradiation light is slow. Accordingly,  
in the present embodiment, the leading edge time  
constant is made faster than the trailing edge time  
constant. Thereby, rapid white display can be  
5 reproduced. Incidentally, there are a variety of  
methods in methods to set change rate of light  
quantity, but here the change rate is set in terms of  
changing quantity per control cycle.

Directions of leading edge and trailing edge are  
10 detected by means to detect trend of change in  
luminance. The change rate is set small so that  
phenomena resembling flickers taking place in the case  
where a rapid change in irradiation luminance is  
executed. Incidentally, according to the present  
15 embodiment, the control speed of irradiation might not  
be so fast in such a direction that light quantity  
decreases, which has turned out to result in unnatural  
appearance.

In addition, in the present embodiment, in order  
20 to cope with such a problem that images resemble  
flickering unless bright/dark trend of irradiation is  
stabilized to a certain degree, the threshold value to  
calculate irradiation light quantity from luminance  
information is caused to have hysteresis so that stable  
25 control is executed by changing the threshold value in  
the leading edge trend and the threshold value in the  
trailing trend (the leading side should be made

larger).

In addition, there takes place a chronological discrepancy between the time when the detected image frame is displayed and the time when light quantity actually changes. In order to improve this, also in this embodiment, change in light quantity is synchronized with displayed images.

Therefore, the image signal delay unit 110 executes delay by temporally storing image signals and thereafter outputting them so as to display images used for calculation in synchronization with timing when light quantity changes.

The image signal delay unit 110 can be realized with a frame memory, etc.

In addition, instead of delaying image signals, control signals may be delayed by the control signal delay unit 111. Although delay takes place between the calculated image and the image to be controlled actually, this case can be realized with delay elements such as several flip-flops, etc. without using a frame memory, etc. at lost costs, making it possible to match a change in light quantity with a change in a display image.

An example of processing flow according to the present embodiment will be shown as follows.

In the case where the image signals are constructed with 8 bits, that input signal will be in

256 gradation of 0 to 255. Here, 0 is assigned to black and 255 is assigned to white display.

[Processing flow 1]

(1) The maximum values RMAX, GMAX and BMAX inside 1  
5 frame or 1 field for each of R, G and B colors are calculated.

(2) An aimed irradiation light quantity Ltg [%] will be expressed by:

$$\text{Ltg} = \text{RGBmax}/255*100$$

10 Wherein, the maximum luminance RGBmax is the largest value among RMAX, BMAX and GMAX.

Here, the actual set values for the aimed irradiation light quantity break down to 10 stages as described below and threshold values are caused to have  
15 hysteresis.

• In case of a leading edge (irradiation light quantity is made bright):

RGBmax Ltg

230 to 255 → 100%

20 204 to 229 → 90%

179 to 203 → 80%

to be followed likewise

• In case of a trailing edge (irradiation light quantity is made dark):

25 RGBmax Ltg

220 to 255 → 100%

194 to 219 → 90%

169 to 193 → 80%

to be followed likewise

(3) With Dup being changing quantity of light quantity per control cycle at the time of leading edge (dark to  
5 bright) and with Ddn being changing quantity of light quantity per control cycle at the time of trailing edge (bright to dark),

The aimed irradiation light quantity and the preceding set light quantity are compared so that the  
10 set irradiation light quantity is caused to increase in the case where the aimed irradiation light quantity is greater than the preceding set light quantity. At that time, when difference between the aimed irradiation  
light quantity and the preceding set light quantity is  
15 larger than Dup, light quantity should not be caused to increase to reach the aimed irradiation light quantity in one control cycle, but increase in light quantity should be limited to Dup.

In addition, the aimed irradiation light quantity  
20 and the preceding set light quantity are compared so that the set irradiation light quantity is caused to decrease in the case where the aimed irradiation light quantity is smaller than the preceding set light  
quantity. At that time, when difference between the  
25 aimed irradiation light quantity and the preceding set light quantity is larger than Ddn, light quantity should not be caused to decrease to reach the aimed

irradiation light quantity in one control cycle, but decrease in light quantity should be limited to Ddn.

An example of program to execute this control process will be expressed as follows.

5 [Equation 1]  
if (aimed irradiation light quantity Ltg)>(preceding set  
light quantity Lw(n-1)) then  
    if((Ltg-Lw(n-1))>Dup)then  
        set irradiation light quantity Lw(n)=Lw(n-1)+Dup  
10 else  
    Lw(n)=Ltg  
    end if  
else  
    if((Lw(n-1)-Ltg)>Ddn) then  
15 set irradiation light quantity Lw(n)=Lw(n-1)+Ddn  
    else  
        Lw(n)=Ltg  
    end if  
end if  
20 (4) Setting of a pulse motor as well as setting of a  
signal gain corresponding with the set irradiation light  
quantity is executed in synchronization with vertical  
synchronization signal VD.  
(5) The above described (1), (2), (3) and (4) are  
25 repeated in every  $\Delta T$  time.

Here,  $\Delta T$  depends on motion speed of the means to control light quantity, and here on motion speed of the

motor to rotate the polarizing plate to change light quantity, but for this processing flow, with a motor having sufficient speed, one frame interval is taken as a control cycle. In addition, in the case where one  
5 frame is constructed with a plurality of fields, a field interval is preferably taken.

[Processing flow 2]

In addition, in the case where motion speed of the motor is slower compared with the frame rate, the  
10 following flow may be used to realize light quantity control effectively.

- (1) The same as the above described processing flow 1.
- (2) The same as the above described processing flow 1.
- (3) The set light quantity  $Lw(n)=Ltg$
- 15 (4) Setting of the pulse motor is set corresponding with the set light quantity.

Here, as for setting of the signal gain, setting is repeated linearly to reach the aimed value in correspondence with change in irradiation light  
20 quantity, in synchronization with VD, during the period when the pulse motor reaches the set value.

- (5) After the pulse motor reaches the set value, the above described (1), (2), (3), and (4) are repeated.

As described so far, also in the case where motion  
25 speed of the motor is slow, display luminance will become maintainable constantly.

[Processing flow 3]

A processing method with histogram of luminance distribution will be described.

(1) An input signal is divided into  $n$  units with  
5 threshold values  $A_0$  to  $A_{(n-1)}$  of the comparator, and  
the number of signals within respective ranges are  
counted so that luminance distribution is created. The  
 $n$ -divided count number should be  $C_0$  to  $C_n$  respectively.  
Here,  $A_{(n-1)} > A_{(n-2)} > \dots > A_0$ .

10 (2) Next, the light quantity value to become an aim is  
calculated by judging whether or not the number is more  
than a predetermined number sequentially in an order of  
luminance intensity from a range with large value.

Here the actual set value is caused to have  
15 hysteresis in the threshold value with the aimed  
irradiation light quantity consisting of 10 stages as  
described below.

• In case of a leading edge (irradiation light  
quantity is made bright):

20 [Equation 2]

if ( $C_n > (100 + \Delta H)$ ) then

aimed irradiation light quantity  $L_{tg} \leq 100\%$

elseif ( $(C_n + C_{(n-1)}) > (100 + \Delta H)$ ) then

aimed irradiation light quantity  $L_{tg} \leq 90\%$

25 elseif ( $(C_n + C_{(n-1)} + C_{(n-2)}) > (100 + \Delta H)$ ) then

aimed irradiation light quantity  $L_{tg} \leq 80\%$

to be followed likewise.

· In case of a trailing edge (irradiation light quantity is made bright):

[Equation 3]

if (Cn>100) then

5        aimed irradiation light quantity Ltg<=100%

elseif ((C(n)+C(n-1))>100) then

        aimed irradiation light quantity Ltg<=90%

elseif ((C(n)+C(n-1)+C(n-2))>100) then

        aimed irradiation light quantity Ltg<=80%

10        to be followed likewise.

        Here, comparative value as well as hysteresis quantity  $\Delta H$  may be changed every count value executing comparison.

(3) The same as the above described processing flow 1  
15 or 2.

(4) The same as the above described processing flow 1  
or 2.

(5) The same as the above described processing flow 1  
or 2.

20        As described so far, according to the present embodiment, the aimed irradiation light quantity is divided into n units, and the threshold value being a judgment value for determining the irradiation light quantity is caused to have hysteresis with the control  
25 trend of irradiation light quantity so that the phenomena causing changes in irradiation light quantity to occur frequently in the vicinity of the threshold

value may disappear, enabling stable images to become available and improving image quality further.

In addition, the time constant setting unit is provided with function of controlling time base changing quantity, in particular, a function to adjust time to practically create changes in light quantity per control cycle so that velocity of changes in light quantity toward a lamp can be controlled (limited), making suitable display realizable.

In addition, irradiation control means with motion speed being slow can be used and are advantageous in terms of costs.

In addition, phenomena like flickers will become controllable.

Thus, according to levels (distribution, features) of inputted image signals, irradiation light quantity is made variable, and means to convert gains or voltage-luminance feature of image signals in correspondence with the irradiation light quantity are provided so that it becomes possible to improve dynamic range while keeping the displayed luminance.

[Embodiment 5]

Next, a fifth embodiment of the present invention will be described.

Fig. 10 is a schematic view showing a construction of an optical system of a liquid crystal projector related to the fifth embodiment of the present

invention, in which reference numeral 1 denotes a reflector for a lamp, reference numeral 2 denotes an arc tube (lamp), reference numeral 3 denotes a fly-eye integrator, reference numeral 4 denotes a PS conversion  
5 optical element and reference numeral 5 denotes a irradiation light quantity modulator. In the irradiation light quantity modulator 5, a phase plate or a polarizing plate is attached to a ultrasonic motor. Reference numerals 6 and 24 denote relay  
10 lenses, reference numerals 7, 9, 11 and 12 denote mirrors, reference numerals 8 and 10 denote a dichroic mirror, reference numerals 13, 14 and 15 denote field lenses, reference numerals 16, 17 and 18 denote liquid crystal panels, reference numerals 19, 20 and 21 denote  
15 polarizing plates, reference numeral 22 denotes a cross prism and reference numeral 23 denotes a projection lens.

A principle on how irradiation light quantity to the liquid crystal panels 16, 17 and 18 is modulated  
20 will be described with reference to Fig. 10. The light fluxes 25 emitted from the lamp 2 are reflected by the reflector 1 to become parallel light fluxes 26. In the present embodiment, the shape of the reflector 1 is parabolic, converting lights into parallel light  
25 fluxes, but it goes without saying that the shape of the reflector is made oval, converting lights into a condensed light flux. The above described light flux

26 is emitted into the fly-eye integrator 3, and  
respective fly-eye lenses 3a in the incident side keeps  
cooperative relationship with the liquid crystal  
panels. This integrator 3 serves to unify distribution  
5 of light flux emitted from the lamp 2, and, in  
addition, to simultaneously unify color distribution  
for respective light emitting areas of the lamp 2.

The light flux emitted from the integrator 3 is  
non-polarized light flux and is converted into a linear  
10 polarized flight flux with the PS conversion element 4.  
As these PS conversion elements, those constructed by  
polarized beam splitters and 1/2-wavelength plates can  
be used. The case of this system sufficiently gives  
rise to the ratio of P light and S light of not less  
15 than 20:1.

When this linearly polarized light flux passes by  
the optical element 5 constructed to rotate the  
polarized plate or the phase plate continually, the  
irradiation light quantity to the liquid crystal panels  
20 continually changes.

In the case where a polarizing plate is used for  
the optical element 5, light quantity (approximately  
85%) with exclusion of approximately 15% being an  
absorbed surface reflection component with the  
25 polarizing plate when the linear polarizing trend after  
passing the above described PS conversion element 4 and  
the polarizer trend of the polarizing plate are

disposed in parallel.

When the polarizing plate is rotated toward the polarizing trend of the above described linear polarized light flux, only projecting component toward the trend of polarizer of the polarizing plate is transmitted so that light quantity can be reduced continually. In the case where the PS ratio of the linearly polarized light flux emitted into the above described optical element 5 is 20:1, irradiation light quantity to the panels could be changed to 1/20.

As described above, after passing the PS conversion element 4, the light flux is converted into linearly polarized light (could be partially linear conversion), and thereafter the polarizing plate through which the linearly polarized light passes is rotated so that the irradiation light quantity onto the panel can be changed. This polarizing plate may basically be disposed anywhere after the PS conversion, but is desirably disposed apart from the light source since light quantity is so intensive when it is disposed near the source that the polarizing plate itself changes in quality. In addition, in the case where it is difficult to dispose it apart from the light source, a polarizing plate made of sapphire can be used to improve its light-resistant and heat-resistant nature.

The above described polarizing plate is rotated

with an ultrasonic motor. The ultrasonic motor (USM) is well controlled at a high speed and in terms of rotary angle, and is suitable for light quantity adjustment for the present objective.

5           For rotation speed of the ultrasonic motor, which depends on load torque, nevertheless 1000 to 5000 rpm is sufficiently attainable, and with rotary angle of 90° (equivalent to white-to-black conversion), irradiation light quantity can be changed in 3 to 15  
10 ms. Image signals scarcely change from white to black rapidly, and with light quantity change of 10%, a necessary rotary angle is 26° and the irradiation light quantity change speed in that case is 1 to 5 ms, being faster than the response speed 10 to 20 ms of liquid  
15 crystal. As for rotary accuracy, rotary angle can be controlled with an encoder mounted on the motor and sufficient accuracy within a range of  $\pm 0.1^\circ$  has been obtained.

          As a motor, besides the ultrasonic motor,  
20 equivalent speed and accuracy is realizable with a stepping motor.

          The above described example is a system in which later-described desired irradiation light quantity is calculated from image signals, and a rotary angle of  
25 polarizing plate for realizing that determined irradiation light quantity is calculated to operate the motor so as to provide that rotary angle.

Next, a system in which the irradiation light quantity itself is monitored, undergoes servo to be controlled to a desired light quantity will be described with reference to Fig. 11. An optical system in Fig. 11 excludes the mirror 7 for the one in Fig. 10 which has been replaced with a half mirror 1101, and adds thereto a condenser 1102 to condense lights having transmitted through the half mirror 1101 and light quantity detector 1103 to detect that light quantity. The half mirror 1101 may be constructed to be approximately reflexive with reflecting component of 99% and penetrating component of 1%. Accordingly, irradiation light quantity to the panels drops slightly with this half mirror, which however is not a level to become a problem. Penetrating light flux from the half mirror 1101 enters the light quantity detector 1103 via the condenser 1102.

A method to control irradiation light quantity to the panels in the optical system in Fig. 11 will be described with reference to a flow chart in Fig. 12. The subsequent irradiation light quantity is determined to be set at which level based on the irradiation light quantity calculated from image signals and the irradiation light quantity at present. The irradiation light quantity at present is taken into consideration, because even if luminance levels change rapidly from white to black due to change of scene, the change

should not be kept up with rapidly, and moderate change at several fields to several tens of fields had better be taken to easily execute operations and the like on the liquid crystal panels, etc., which are visible to human eyes without causing any uncomfortable feeling, and are adaptable to such cases.

After the above described level of irradiation light quantity is determined, the motor is rotated so as to provide with that irradiation level so that actual light quantity after control is measured with the light quantity detector 1103. Due to the light which is condensed by the condenser 1102, the detector which itself is a small sized pin type one will work sufficiently, and can detect light quantity in several 10  $\mu$ s in combination with a rapid amplifier. If the motor is controlled to make this light quantity to reach a desired level, irradiation with constant light quantity is realized and a stable image plane is realized even if change in light quantity takes place in the lamp itself. In particular, in case of using a very high pressure mercury lamp and a metal halide lamp being effective to make a project engine smaller and having arc length being short with 1 to 1.3 mm, movement of the emission area of the lamp 2 could give rise to change in light quantity emitted into the integrator 3 and change in practical irradiation light quantity to the panels, resulting in deteriorating

display performance, and settlement on that has been demanded, and now that can be dealt with effectively and display performance can be advantageously improved.

In addition, signals corresponding with actually  
5 detected light quantity are calculated to be written in the liquid crystal panels, etc., enabling such operation that switches irradiation light slowly for change in image from white to black and fast for change from black to white. This serves to secure a peak  
10 luminance of white for change from black to white, giving rise to advantages that not only display performance is improved but also load on the motor is reduced, consumed power saving becomes possible and life of the motor is extended.

15 Here, an ultrasonic motor is used to rotate the polarizing plate to execute irradiation light quantity control that is rapid, without any backlash, and is excellent in calmness. However, it goes without saying that another motor other than the ultrasonic motor is  
20 usable.

The above described construction controlled irradiation light quantity with rotation of the polarizing plate, but instead of this polarizing plate, uses a phase plate which gives rise to few light  
25 quantity losses and is suitable as a high luminance projector. As the phase plate, a  $\lambda/2$  plate is adopted so that the phase of the linear polarized light flux

after passing the  $\lambda/2$  plate rotates by  $2\theta$  in  
correspondence with the rotary angle  $\theta$  of the  $\lambda/2$  plate  
toward a linear polarized light flux emitted from the  
PS conversion element 4. Accordingly, the rotary angle  
5 of the  $\lambda/2$  plate may be a half toward the polarizing  
plate, enabling more rapid light quantity modulation.  
The light quantity of the rotated polarized light flux  
suffers from loss with the phase plate is 2 to 3% at  
most, and is excellent in providing with high  
10 luminance. The polarizing plate preceding the liquid  
crystal panel illuminates only that inclined projection  
component to the liquid crystal panels, and thus  
irradiation light quantity can be modulated.

In the optical system in Fig. 10 and Fig. 11, the  
15 light flux having transmitted through the optical  
element for irradiation light quantity modulation  
(irradiation light quantity modulator) 5 is illuminated  
to the liquid crystal panels for respective color via  
relay lenses 6 and 24. The dichroic mirror 8 transmits  
20 the blue color but reflects others. The dichroic  
mirror 10 transmits the red color and reflects the  
green color. In this case, reference numeral 16  
denotes the liquid crystal panel for the blue color,  
reference numeral 17 denotes the liquid crystal panel  
25 for the green color and reference numeral 18 denotes  
the liquid crystal panel for the red color, which is  
for example a TN liquid crystal panel to be driven with

a TFT. Moreover, as concerns the one with micro lenses for respective pixels, shading of lights at the opening decreases and provision of high luminance has been planned.

5           Accompanied by irradiation light quantity conversion, a new method is adopted also for driving the above described liquid crystal panels. This driving method will be described later. The light fluxes for respective colors subject to modulation with  
10           the respective color liquid crystal panels are synthesized with the cross prism 22 and are shown on image plane via the projection lens 23.

[Embodiment 6]

Fig. 13 is a schematic view showing a sixth  
15           embodiment of the present invention. In Fig. 13, lights emitted from a light source 1301 such as a metal halide lamp and a xenon lamp, ext. are made to go approximately in parallel with the parabolic reflector 1302 and subject to reflection on the mirror 1303, and  
20           form a light source image in the position of the front end surface (a first end surface) 1305-1 of the integrator 1305 via the condenser 1304. In the vicinity of this light source image, a diaphragm indicated by 1310 is provided. When the diaphragm 1310  
25           is restricted, incident light quantity for the integrator 1305 can be decreased. In the light flux emitted into the integrator 105, a portion transmitted

through the integrator and a portion of the remaining portion is emitted from the rear end surface (a second end surface) 1305-2 subject to one to several reflections on the internal reflection surface.

5           It is advisable that a parabolic reflector 1302 and a condenser 1304 fulfilling  $4 \leq F4/F3 \leq 10$ , (where  $F3$  is distance from the bottom surface of the above described parabolic reflector to the above described focus) with  $F3$  being the focal distance of the  
10           parabolic reflector 1302 and  $F4$  being the focal distance of the condenser 1304. The reason thereof is that a small light source image can be formed in the front end surface position 1305-1 of the integrator 1305. The light flux from the integrator 1305 is  
15           emitted into the convex lens 1306, transmitted therethrough the dichroic filter 1311 which only RGB or RGBW lights transmitted therethrough, and forms the image of the light source 1301 in the vicinity of the reflection mirror 1307. The above described dichroic  
20           filter is exemplified by a penetration type, but it goes without saying that a reflection type is effectively used. The reflection mirror 1307 is disposed in a position of the opening diaphragm 1313 of the projection lens 1314.

25           In Fig. 13, the light flux from the integrator 1305 is reflected by the reflection mirror 1307 and is emitted to a plane convex lens 1308 so as to be made to

become approximately parallel lights with the plane  
convex lens 1308 and to illuminate the DMD panel 1309  
being a light modulator. The DMD panel 1309 forms  
image information by light modulation such as  
5 scattering or non-scattering of incident lights for  
each pixel corresponding with image signals. The  
liquid crystal display panel of the above described  
fifth embodiment has similar construction and  
functions, and as necessity arises an liquid crystal  
10 display panel of another type can be used.

An important point in the optical system of the  
present embodiment is that a convex lens 1306 being the  
rear end surface of the integrator 1305 and the plane  
convex lens 1308 form an image on the DMD panel 1309.  
15 In the rear end surface 1305-2 of the integrator 1305,  
the light flux penetrating inside the integrator 1305  
without any reflection and the light fluxes subject to  
one or several reflections are overlapped, and thereby  
unevenness in color and unevenness in luminance does  
20 not take place to give rise to approximately uniform  
light intensity distribution. Accordingly, if this  
rear end surface 1305-2 is brought into cooperative  
relationship with the display surface of the DMD panel  
1309 by way of the convex lens 1306 and the plane  
25 convex lens 1308, display surface of the DMD panel  
alleviate unevenness in color and unevenness in  
luminance and as a result thereof, unevenness in color

and unevenness in luminance of images displayed on the image plane 1315 are alleviated. In addition, the shape of the rear end surface 1305-2 of the integrator 1305 is made to be a rectangular approximately similar in shape with the display surface of the DMD panel 1309 so that the rear end surface 1305-2 of the integrator 1305 is made to form an image on the DMD panel 1309 at an appropriate magnifying ratio to illuminate the panel efficiently.

Incidentally, in Fig. 13, the lens 1304, the lens 1306 and the lens 1308 are respectively one lenses, but these lens system can be constructed by a plurality of lenses respectively. Respective lenses of the above described embodiments are constructed likewise.

Accordingly, the term referred to as "convex lens" in the present application is a lens system having positive refraction force.

With the DMD panel 1309, the reflection lights of respective colors modulated corresponding with image signals are condensed by the plane convex lens 1308, and at least a portion of the flux passes the opening of the opening diaphragm 1313 and is projected on the image plane 1315 via the projection lens 1314. At this time, in the opening of the diaphragm 1313, a light source image similar in shape with the light source image is formed with the light subject to regular reflection by the DMD panel 1309. The reason hereof is

that the light source 1301, the front end surface 1305-  
1 of the integrator 1305, the reflection mirror 1307  
and the opening diaphragm 1313 are disposed in a  
cooperative positions each other. The optical system  
5 consisting of the projection lens 1314 and the  
condenser 1308 is a system that is telecentric in the  
DMD panel side.

The present embodiment is a system to display RGB  
with time division by way of rotation of the dichroic  
10 filter 1311 shown in Fig. 13, and the diaphragm 1310  
for light quantity adjustment is modulated in  
synchronization with one rotation so that luminance  
modulation similar to the fifth embodiment can be  
executed. In addition, the diaphragm 1310 is adjusted  
15 in synchronization with respective color levels of the  
RGB time division so that irradiation light quantity  
can be also modulated.

The present construction is advantageous in  
costing little either to execute irradiation light  
20 quantity modulation to provide the high dynamic range  
DMD with further highly dynamic range high image  
quality.

The above described embodiment has been  
exemplified by the DMD panel, but it goes without  
25 saying that the liquid crystal panels are effective in  
this respect.

[Embodiment 7]

Figs. 14A and 14B are block diagrams showing an electric system related to a seventh embodiment of the present invention. In Figs. 14A and 14B, reference numeral 1400 denotes a DMD and reference numeral 1401 denotes a DMD driver unit. The driver unit 1401 comprises internally a unit 1402 of signal conversion processing such as time division, etc., a memory 1403, a control unit 1404 and a reset driver 1405.

Coupled with signal processing, there is a color filter system 1406 (corresponding to 1311 in Fig. 13), which is constituted by control on rotation synchronization and servo 1407 as well as the color filter 1408 itself.

The diaphragm 1409, the power source unit 1410 and the DMD driver unit 1401 are connected with the micro computer 1462 and are controlled in their entirety.

The power source unit 1410 consists of the ballast 1411, the power source 1412, the lamp 1413, the lamp fan 1414 and the fan for cooling the power source and the electronic substrate 1415. In addition, a user interface unit 1416 comprising a remote controller and buttons is constructed by the remote controller 1417, the LED 1418 to emit lights from the remote controller, buttons and keys 1419, and switches 1420.

The acoustic system 1421 comprises a DA unit 1422 to DA convert output signals of digital signals 1/F

such as LVDS and TMDS, a volume (VOL) adjusting circuit 1423, an amplifier 1424 and speakers 1425.

As a monitoring function 1461, an S terminal 1426, a component video terminal 1427, a composite video terminal 1428 and a terminal for digital broadcasting (D3) 1429, etc. are provided.

On the other hand, analog signals from the PC are inputted from the Dsub 15 pins 1430; converted into digital signals at the AD converter 1434 via phase adjustment 1431, PLL 1432 and the preamplifier 1433; and enter a scan converter 1436 via a multiplexer 1435.

In addition, signals for DTV enter the scan converter 1436 via a tuner unit 1437 and an MPEG decoder 1438. Normal NTSC signals are inputted via the scan converter 1436 after AD conversion in the AD converter 1451. In addition, audio signals separated from signals for DTV and NTSC signals enter the transmission unit 1455 of an LVDS interface via a multiplexer 1452. Video signals from the scan converter 1436 and audio signals from the multiplexer 1452 enter a front end 1454 and an acoustic system 1421 via the transmission unit 1455 of the LVDS interface and the receiver unit 1453. Output signals of the front end 1454 enter the DMD driver unit 1401.

The present construction not only makes high image quality available for a front projector and a rear projector for office use but also is applicable to rear

or front TVs with large image planes for consumer use, home theaters and mini theaters, etc.

In Figs. 14A and 14B, the DTV tuner unit 1463 comprises a tuner 1464, an SAW filter 1439, an AD converter 1440, a VSB demodulator 1441 and a demixer 1442. An MPEG decoder 1438 comprises a video decoder 1443 and an audio decoder 1444. An NTSC tuner 1445 comprises a tuner 1446, an SAW filter 1447, an NTSC demodulator 1448, an audio decoder 1449 and an AD converter 1450.

As described so far, according to the embodiment of the present invention, the irradiation light quantity control means are provided to adjust light quantity illuminated to the light modulator so that a dark image plane can be illuminated with low light quantity while a bright image plane can be illuminated with high light quantity, and as a result, contrast higher than in the case of irradiating the light modulator at a constant light quantity can be realized.

According to the embodiment of the present invention, the irradiation light quantity modulating means have been provided between the light source and the light modulator so that a dark image plane can be illuminated with low light quantity while a bright image plane can be illuminated with high light quantity, and as a result, contrast higher than in the case of irradiating the light modulator at a constant

light quantity can be realized.

According to the embodiment of the present invention, the irradiation light quantity modulating means have been provided to directly control the light source emitting lights to be illuminated to the light modulator so that a dark image plane can be illuminated with low light quantity while a bright image plane can be illuminated with high light quantity, and as a result, contrast higher than in the case of irradiating the light modulator at a constant light quantity can be realized.

According to the embodiment of the present invention, light quantity is controlled to keep relationship approximately in inverse proportion to signal amplifying ratio so that high contrast can be realized while display luminance in an intermediate gradation is kept at a constant.

As described in the embodiments in particular so far, according to the invention of the present application, image display with high image quality can be realized.